REVIEW

NEXT GENERATION SPACE TELESCOPE SOFTWARE MANAGEMENT PLAN

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Prepared for

NASA Goddard Space Flight Center
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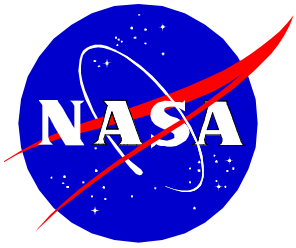

NEXT GENERATION SPACE TELESCOPE
SOFTWARE MANAGEMENT PLAN

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1 INTRODUCTION

The Next Generation Space Telescope (NGST), which is currently scheduled for launch in 2008, will perform astronomical observations from a location orbiting the Earth-Sun L2 libration point. The NGST system is composed of a flight segment (spacecraft) and a ground segment that must inter-operate effectively to achieve goals for observing efficiency and science productivity while simultaneously making efficient use of operational resources. Both the flight and ground segments have substantial software complements that must be developed and subsequently maintained throughout the mission lifetime.

This is the Software Management Plan (SMP) for the NGST Project. The NGST Project is the Acquirer of software capabilities and related services. These capabilities and related services will be provided by other NASA organizations, universities, general and mission support contractors or contractors providing end-items with embedded and support software. This plan describes the management and technical approaches and methods that will be employed in the development of that software so that operability and performance goals are achieved while effectively controlling development and sustaining engineering costs.

Throughout this document the term "Project" is used to refer to the NGST Project in its role of software Acquirer. The term "Provider" is used to refer to developers and integrators of software and software services regardless of the nature of their organization or their affiliation with the Project. Regarding “off-the-shelf” software products, Providers include buyers and integrators of the products but generally not the original developers.

1.1 NGST Project Summary

Extensive descriptive information regarding NGST and the Project may be found at the NGST web site (see URL: http://ngst.gsfc.nasa.gov/).

1.2 Purpose and Scope

This SMP establishes the Project's goals, organization, and management processes, for the acquisition of all software products to be provided to the Project to satisfy its requirements. This includes the development and integration of software for both the flight and ground segments, and for laboratory, test, and development tools and environments. The term "software" as used in this document includes code, documentation, and associated data.

This SMP contains requirements to be satisfied by the providers of all software purchased, contractually acquired, developed or maintained for the support or execution of the mission. It defines standards, procedures and organizational relationships for all software activities associated with the Project. Its provisions apply to all Government organizations, in-house activities and contractors providing software capabilities to the Project.

The SMP does not describe the details of software segment development projects. It is expected that each Provider of software will prepare a Software Management Plan or Product Plan containing the necessary details for that component. This SMP provides a model for provider SMPs or Product Plans and can be referenced where appropriate to reduce effort and minimize redundancy. Providers proprietary processes are acceptable if they meet the intent of this SMP. The remainder of this document will use the term SMP to designate the planning document required of each software provider with the understanding that a Product Plan or other appropriate document may be used for the same purpose.

This SMP does not apply to operational institutional capabilities, such as flight dynamics, that are not specifically developed or modified to support the Project. However, software and hardware interfaces between operational institutional capabilities and NGST Project capabilities, and schedules for the availability of support resources must be specified.

1.3 Document Status and Evolution

This version of the Plan has been updated from the original draft release in March 2000 to prepare for the requirements of Phase 2 and incorporates suggestions from both contractors and government personnel. The Plan will be reviewed by the NGST Software Managers at each major system review, or at six-month intervals, which ever is shorter. Needed changes will be made subsequent to each review.

1.4 Document Organization

This SMP is organized as follows:

- Section 1 presents the purpose and scope and provides an overview of the context, structure, and content of this Software Management Plan (SMP).
- Section 2 identifies documents that are referred to in this SMP or that provide useful additional information.
- Section 3 identifies and provides a description of the software that the Project will acquire.
- Section 4 defines the management approach to be used by the Project to plan, coordinate, direct and monitor the software development activities.
- Section 5 defines the Project's approach for coordinating and regulating the technical activities of the software development process.
- Section 6 describes the Project’s framework for ensuring that the software systems developed under this plan are complete, consistent, and meet applicable standards.
- Section 7 provides definitions of all abbreviations and acronyms use in this document.

2 RELATED DOCUMENTATION

2.1 Parent Documents

1. NPD 7120.4A, NASA Policy Directive, Program/Project Management, November 14, 1996. http://nodis.hq.nasa.gov/Library/Directives/NASA-WIDE/Policies/Program_Formulation/N_PD_7120_4A.html
2. NPG: 7120.5A NASA Procedures and Guidelines, NASA Program and Project Management Processes and Requirements, April 3, 1998, http://nodis.hq.nasa.gov/Library/Directives/NASA-WIDE/Procedures/Program_Formulation/N_PG_7120_5A/contents.html

2.2 Applicable Documents

3. NGST Mission Requirements Document, TBD
4. Configuration Control Requirements, GSFC 400-PG-8700.2.1, http://engrwbserv.gsfc.nasa.gov/gdms/docs/pgwi400/400-PG-8700.2.1-.pdf
5. The GSFC Quality Manual, GPG 8730.3C, http://engrwbserv.gsfc.nasa.gov/gdms/docs/GPG8000/GPG-8730.3C.pdf
6. NASA-STD-2201-93, Software Assurance Standard, November 10, 1992
7. NASA-STD-2100-91, Software Documentation Standard
8. NASA-STD-2202-93, Software Formal Inspections Standard

2.3 Information Documents

9. GSFC Software Engineering Laboratory, SEL-84-101, Manager's Handbook For Software Development, November 1990.
10. GSFC Software Engineering Laboratory, SEL-81-305, Recommended Approach to Software Development, June 1992.
11. NASA Systems Engineering Handbook, SP-6105, June 1995.
12. Std. 610.12-1990 IEEE Standard Glossary of Software Engineering Terminology
13. Std. 1233-1998 IEEE Guide for Developing System Requirements Specifications
14. Std. 830-1998 IEEE Recommended Practice for Software Requirements Specifications
15. Std. 1008-1987 (R1993) IEEE Standard for Software Unit Testing
16. Std. 829-1998 IEEE Standard for Software Test Documentation
17. Std. 1012-1998 IEEE Standard for Software Verification and Validation
18. Std. 1059-1993 IEEE Guide for Software Verification and Validation Plans
19. Std. 1028-1997 IEEE Standard for Software Reviews
20. Std. 1045-1992 IEEE Standard for Software Productivity Metrics
21. Std. 982.1-1988 IEEE Standard Dictionary of Measures to Produce Reliable Software
22. Std. 1061-1998 IEEE Standard for a Software Quality Metrics Methodology
23. Std. 730-1998 IEEE Standard for Software Quality Assurance Plans

3 NGST PROJECT SOFTWARE DEVELOPMENT OVERVIEW

This section provides an overview of the software components and the software development aspects of the NGST project.

3.1 Project Software Development Goals

The goals for NGST software development are intended to directly support the NGST Project Goals for acquiring scientific knowledge as stated in the Goals section of the NGST World Wide Web site. The overarching goals of the NGST Software Development activities are to:

- Achieve robust and effective end-to-end operability from operations planning through capture and analysis of science and engineering data.
  - Encourage and participate in the development of appropriate operations concept analysis and documentation, and fully utilize these products in the development process to improve operability of the resulting system.
  - Encourage and support effective communication between development, integration, validation, and operations teams, and between development teams for the various system segments, to promote common understanding of operations and design concepts.
- Achieve high efficiency and effectiveness in the software development and sustaining engineering processes.
  - Encourage the appropriate use of common components, languages, software tools, development environments, and ground support components for design, development, integration, and sustaining engineering.
  - Encourage thorough and uniform approaches, methods, tools and formats for software design and documentation.
  - Carefully manage all aspects of the project life cycle including the development processes, the system configurations and the risks.
  - Carefully plan and monitor the allocation of resources to development activities to ensure effective and efficient use of those resources.

3.2 System Overview

NGST is composed of a spacecraft, a ground system for planning, conducting and managing operations, and several development and test facilities. At the time of this edition of the SMP, Pre-Phase A studies have been completed resulting in several NGST concepts, one of which is the GSFC Yardstick Concept. While Phase A activities in progress are generating more mature concepts, the work of the prime contractors is procurement sensitive and will not be reflected here for the present. The main NGST segments are described briefly below based on the GSFC Yardstick as the nominal configuration. More information is available on the NGST web site at http://ngst.gsfc.nasa.gov.

3.2.1 NGST Spacecraft

The NGST spacecraft is composed of the Space Support Module (SSM), the Optical Telescope Assembly (OTA), and the Integrated Science Instrument Module (ISIM). A sunshield provides passive cooling for the OTA and ISIM by blocking sunlight (cold side). The SSM houses control electronics that are placed on the sun side of the sunshield (warm side). Each of these components is described below.

3.2.1.1 SSM

The SSM provides the main structural elements that support the launch and deployment phases of the mission, the platform to which the sunshield is fixed, and the truss that connects to the ISIM and OTA. The SSM also houses the data systems and the control electronics and mechanisms for the spacecraft. The principal functions of the SSM Data System are Command and Data Handling, Attitude and Orbit Control, Propulsion, Power, Thermal, Communications, and Health and Safety. The Flight Software associated with these functions is a significant component to be provided under this plan.

3.2.1.2 OTA

The OTA consists of the telescope mirrors and the hardware and software elements required to monitor and control them. There are four mirrors. The segmented primary mirror and the secondary mirror are open to free space, while the tertiary mirror, and fast steering mirror are inside the ISIM box. The control software for these elements resides in data system components housed in the SSM and is covered under this plan.

3.2.1.3 ISIM

The ISIM consists of a physical structure that houses three of the OTA subsystem mirrors (tertiary, and fast steering), the three science instruments (SIs), and associated hardware and electronics. The three SIs, as defined in the GSFC Yardstick concept, are the Near Infrared Camera, the Near Infrared Spectrograph, and the combined Mid Infrared Camera/Spectrograph. Each of the SIs has a multi-configuration optical/mechanical system for transmission of the light and a focal plane array (FPA) detector system for measuring the incident light. The data systems and software elements required to monitor and control these components reside in the ISIM. The ISIM Flight Software as well as the software for the three SIs are covered under this plan.

3.2.2 Ground System

The NGST Ground System consists of a network of software components that work together to support the planning and conduct of science and spacecraft operations and the processing, handling and distribution of the resulting data. This software, covered under this plan, addresses the following major functions:

- Observing Proposal Preparation
- Planning and Scheduling
- Operations Control Center
- Science Data Processing
- Data Archive

3.2.3 Development, Test, and Sustaining Engineering Facilities

The development, integration, testing and maintenance of the various NGST software systems require the support of a number of laboratories, development environments, simulators, and test facilities. These entities must be addressed either with separate SMPs or included in the SMPs for other software components. In some cases, the need for additional test facilities may be

identified during integration and test planning in which case they may be addressed in an Integration and Test Plan.

3.2.4 Launch Vehicle

There are no software components related to the launch vehicle, known at this time, to be developed under this plan. There may be interface issues related to the vehicle integration and launch phases that will involve integration and test activities and personnel. Additionally, there may be requirements associated with commanding and monitoring in the launch environment that require special consideration.

3.3 Project Features

This section describes some of the prominent features of the NGST Project.

3.3.1 Project Phases

There are two different designations for the phases of the NGST Project, one designation is related to selection of the prime contractor, and the other relates to the traditional system development model.

In the first case, the NGST Project is divided into two phases in accordance with the process for selection of the prime contractor. Phase 1 is characterized by the selection of two prime contractors, Lockheed-Martin and TRW, who are working in tandem leading to the selection of a single prime contractor. The selection of the single prime contractor begins Phase 2.

A second designation of project phases corresponds to the traditional NASA system development model with phases named A through E defined as follows.

Phase A – Preliminary Analysis

Phase B – Definition

Phase C – Design

Phase D – Development

Phase E – Operations

The NGST Project Top Level Observatory Schedule can be found on the NSGT web site at http://ngst.gsfc.nasa.gov. As this schedule shows, Phase 1 includes Phase A and early Phase B. Phase 2 includes the remainder of Phase B and Phases C and D.

For the purpose of describing the software development life cycle model in this SMP (see Section 5.1.1) and consistent with the NASA System Engineering Handbook (Reference 11), we refer to the activities that generally occur in Phases A and B as the Formulation Phase, Phases C and D as the Implementation Phase, and Phase E as the Operations and Maintenance Phase. We do this because we are more interested in identifying the types of activity and the products rather than the project assigned dates, since individual software providers may develop components on a schedule that is staggered from the project schedule.

3.3.2 Major Milestones

High-level schedules showing the major NGST milestones may be found on the NGST web site at http://ngst.gsfc.nasa.gov.

3.3.3 Engineering Teams

Several different teams are presently working on various aspect of the NGST. A description of these teams may be found on the NGST web site at http://ngst.gsfc.nasa.gov.

3.3.4 Concurrent Engineering

NGST Software Development activities will employ concurrent engineering approaches to the greatest extent practicable. This means that the major stakeholders in the process will be involved at all stages of development whenever this can significantly improve the cost-effectiveness of the development process and the final products. Involvement of design, implementation, integration and operations personnel in all development activities is strongly encouraged.

3.4 Project Organization

The Project's organization structure may be found at http://ngst.gsfc.nasa.gov under "Project Office" and "Who's who".

Table 3-1 below summarizes the roles of the principal organizational entities in the NGST environment.

3.5 Information Infrastructure

The NGST Project promotes the use of intranet, the Internet, the World Wide Web and email to enable and encourage communication and information dissemination across the project, and among international partners. The Software Operations Working Group (SOWG) will utilize these same media to disseminate technical information, documentation related to software projects, and schedule information regarding upcoming meetings, reviews and walkthroughs. See section 4.2.2 for more information on the SOWG.

Standard approaches and formats for documentation will be encouraged to simplify posting procedures and promote broader understanding of technical materials. In particular, requirements and design information should be available over the intranet for review by cognizant technical personnel.

The SOWG will encourage the convening of appropriate and focused meetings and splinter groups to work specific issues and problems with appropriate staff present to fully represent the stakeholders in the issue and the expertise needed to resolve it.

The SOWG will encourage the automation of project processes, like Configuration Management and System Engineering tools, that provide general access to technical and configuration information. The broad use of specific tools will be encouraged, as appropriate, to promote sharing of information by various users of the tools.

Table 3-1. Roles of Principle NGST Organizational Elements

NGST Project (GSFC Code 443)	Systems Engineering Lead SOWG SSM Management ISIM Management ISIM Space Frame Science Oversight SI Management International Coordination
Space Telescope Science Institute	Ground System Development Mission Operations Science Operations Science Community and Education Outreach
Electrical Systems Center (GSFC Code 560)	Flight Data Systems Hardware
Information Systems Center (GSFC Code 580)	Flight Software Management Common C&DH Development ISIM Software Development Test Tools & Facilities Development
Prime Contractor	Spacecraft Development · Spacecraft Support Module · Optical Telescope Assembly · Sunshade · Integration & Test · Systems Modeling & Testbed
Science Community	Instrument Definition Science Advocacy Education & Public Outreach Data Analysis
International Partners	Instrument Definition Spacecraft/Telescope Contributions
SI Development Contractors	Science Instrument Development

4 MANAGEMENT APPROACH

This section describes the methods and processes the Project will use to manage the business and technical aspects of its software develop process. It specifies how the Project will plan the work and estimate costs, assess progress, and review products. It describes the principal software management roles and responsibilities and identifies requirements to be levied on software providers to develop and submit business related information needed to accomplish project objectives.

4.1 Management Objectives and Priorities

The Project's approach to managing the development of Project software is intended to ensure, in priority order, (a) that functional, performance and quality requirements are satisfied, (b) that resources are used effectively across the entire life cycle, and (c) that delivery schedules are met.

Pursuant to these objectives, the project will:

- Create and maintain a software management organization that embodies and exploits the project's priority for open communication and information sharing.
- Establish appropriate management methods and practices.
- Maintain awareness of status and progress against schedules and budget.
- Identify and manage areas of risk.
- Establish formal methods and tools for tracking system components and configurations.

4.2 Software Management Organization

The NGST software management organization will be headed by two NGST Software Managers, one focused on the ground software and the other focused on the flight software. The NGST Software Managers are assigned the primary responsibility for ensuring that the NGST software development management objectives are met. A Software Operations Working Group (SOWG) assists in the coordination and direction of software development activities. The SOWG is composed of representatives from Goddard Space Flight Center, the Space Telescope Science Institute, and the providers' software organizations.

4.2.1 Software Management Responsibilities

The NGST Project will identify two Software Managers (SM) who are responsible for ensuring that software being acquired by the Project meets requirements and is delivered on schedule and within budget. One of the Software Managers focuses on ground software and reports to the NGST System Engineer and the other focuses on the flight software and reports to the NGST Project Manager. The SMs' responsibilities include the following:

- review and approve providers' software management plans.
- ensure, at the conclusion of each life cycle phase, that re-estimations of software size, effort, and schedule are made and analyzed.
- serve as chairperson at the software portion of all major reviews. The SM will ensure that all review items are resolved.
- ensure that provider software is delivered in accordance with the Project Master Schedule.

- co-chair the Software Operations Working Group.
- provide technical direction to software providers and support contractors especially on issues which potentially have long-term effects on system schedule and cost.
- ensure commonality of software, hardware and tools where possible to minimize life-cycle cost to the project. Providers will utilize project resources when necessary to ensure the common usage of hardware, software and tools. Providers will identify in their SMP those items they expect will be provided by the Project.
- ensure that all software assurance and configuration management functions are performed.

4.2.2 Software Operations Working Group

The Software Operations Working Group (SOWG) is chaired by the Software Manager and has, among its members, representatives from each of the providers' software organizations. The Software Manager coordinates the activities of the SOWG to accomplish the Software Management responsibilities listed in Section 4.2.1 above.

The SOWG also performs the following functions:

- Coordinates with NGST Systems Engineering groups
- Influences commonality across all software systems. Specific software teams work technical details and interfaces
- Promotes effective systems and software engineering (related to system architecture, policies and practices) for benefit of design, development, I&T and sustaining engineering
- Coordinates SW requirements and interface definitions
- Establishes goals, concepts and approaches for strategic and tactical problems and issues related to the software development activities
- Tracks baseline products to ensure consistency with build and integration plans
- Resolves SW end-to-end operational issues

4.2.3 Provider Organizational Requirements

Software providers shall designate software management representatives who will serve as points-of-contact for the SOWG. In general, the providers' software representatives will serve as members of the SOWG and will act as liaison between the SOWG and the providers' software organizations to help coordinate the providers' software development activities in accordance with the Projects goals and objectives. The exception to this is that, during the prime contract competitive phase, Phase 1 contractors will not be members of the SOWG but will attend certain scheduled SOWG meetings designated as open. However, after the selection of the Phase 2 prime contractor, the prime contractor will have membership and will send a representative to the SOWG meetings.

4.3 Planning, Monitoring and Controlling Mechanisms

Adequate methods and processes for planning, monitoring, assessing progress and status, and taking corrective action are essential to fulfilling the Project's objectives for satisfying technical requirements, meeting delivery schedules, and using resources effectively.

4.3.1 Planning and Estimating

The Project, GSFC Code 580, the Prime Contractors, SI contractors, and the Science Institute, shall establish cost estimates and a Master Schedule based on the WBS described below. Progress and status will be tracked against the WBS structure. Proprietary information will be segregated to prevent inappropriate disclosure.

4.3.1.1 Work Breakdown Structure

Each software provider shall develop a Work Breakdown Structure (WBS) for use in planning and costing its work. Each provider shall coordinate this WBS with appropriate project personnel to ensure proper integration into the project WBS.

The Phase 2 Work Breakdown Structure for the NGST Project is as follows:

1. Project Management
2. Science
3. Observatory Systems Engineering
4. Integration and Test (I&T)
5. Optical Telescope Assembly (OTA) Technology Development
6. Sunshield
7. Spacecraft Support Module (SSM)
8. Integrated Science Instrument Module (ISIM)
9. Flight software
10. Launch Vehicle
11. Ground Segment and Operations

Ground software development and integration activities will be allocated to lower-level WBS structures under the WBS item related to the associated system segment. In developing lower-level WBS structures, the following items should be considered:

- Segment System/Subsystem/Component structure – Significant system elements are typically allocated to higher WBS elements than the activities that implement them so that resources can be traced to tangible products.
- Planning and Management - includes the development and administration of all software planning information involving cost, schedule and risk, management and control board meetings, and management reviews.
- Acquisition/Purchase - includes the development of all procurement and purchase documents, source selection activities, and acceptance testing of commercial off-the-shelf (COTS) software.
- Logistics and Administrative Support - activities required to acquire and distribute software development supplies and materials; activities required to maintain and operate equipment

and facilities used by the development staff. Includes transportation of equipment and staff travel.

- Formulation - includes all conceptual engineering; encompassing development of "throw away" prototypes, supporting analysis, requirements definition, and the development of architecture design documentation.
- Implementation - activities associated with the production and control of computer code including modification or enhancement of inherited, purchased or government furnished software and operation of software development repositories.
- Operation and Maintenance - activities required to effectively utilize software that has been established as an operational baseline, to enhance the software in response to changing requirements or user concerns, and to correct operational deficiencies.
- Performance Assurance - with the exception of Verification and Validation includes all software assurance functions described in Section 6.
- Verification and Validation - includes the tracing, testing and analysis activities described in Section 6.3 of this plan.

4.3.1.2 Activity Identification

Estimation will begin with identification of activities and elements of cost as the definition of Work Packages of a granularity appropriate to the phase of the project. Consideration should be given to the life cycle model described in Section 5.1.1

Providers shall identify requirements for new, modified and commercial or furnished software components. Software units having common application, if any, shall be specifically identified. Estimates shall be provided of estimated total lines of code broken into appropriate categories.

Revisions to the code size estimates shall be developed by providers at major reviews such as the System Requirements Review (SRR), the Preliminary Design Review (PDR), and the Critical Design Review (CDR).

4.3.1.3 Resource Requirements

Estimates of resource requirements shall be compiled by each provider and aggregated by the Software Manager to provide budget information to the Project and create a basis for monitoring activities. Estimates will take into account the following resource categories:

- Labor
- Equipment
- Materials, Facilities, and other Resources
- Management Reserves

The provider's SMP shall describe how development staff hours will be allocated to each WBS element for each life cycle phase. Other resources such as travel, equipment, materials, and facilities shall also be listed in the provider's SMP. The actual resource data will be maintained separately.

4.3.1.4 Assumptions, Dependencies, and Constraints

Providers shall determine existence of dependencies among work packages and on external factors. Also, providers shall identify any assumptions that have been made regarding circumstances or conditions enabling the performance of any of the work packages, and any constraints or conditions that must be met to accomplish the objectives of any work package.

These assumptions, constraints, and dependencies, along with estimates and schedules, will be reviewed by the SOWG, which will contribute to broader understanding of the intricacies of the project and the relationships among the providers.

4.3.1.5 Budget and Resource Allocation

Providers shall identify specific resources to be allocated to work packages to meet the resource requirements identified as described in Section 4.3.1.3.

4.3.1.6 Schedules

The Project will maintain a Master Schedule showing the dates of key events. Providers shall produce schedules, consistent with the Project Master Schedule, showing planned start and end dates for the activities defined by the work packages. These schedules will incorporate the dependencies and resource allocations described in Sections 4.3.1.4 and 4.3.1.5. Use of an automated tool is strongly recommended. Resulting schedules will be discussed in the SOWG, presented at major reviews, and will be posted on the Project or provider web site for access via the intranet.

4.3.2 Progress Assessment

Each provider shall routinely prepare and forward monthly software management and status reports to the Project. These reports shall provide numerical assessments of the status of each activity underway with regard to schedule, cost, staffing and risk. These reports will be aggregated by the Software Manager to present an encompassing summary of the Project software development efforts.

4.3.3 Reviews

This section addresses two types of reviews: (1) formal, project-level reviews, before a review board, and (2) less formal, on-project, software-only reviews. Formal external reviews will be conducted at significant points along the development life cycle, and pertinent information on software systems will be presented at all these reviews. Refer to Project schedules and major contract Statements of Work for details of specific formal project-level reviews.

Each formal review shall include a Software Management Review. The Software Management Review will address the current status of the provider's software accomplishments. The review will present technical plans and accomplishments as well as planned and actual expended staff-hours, available resources and schedules. The software provider shall provide updated estimates of cost- and schedule-to-complete for Project review and approval. The accepted estimates will be used for assessment during the next phase of development.

Software-only reviews at the subsystem level will be held as appropriate throughout the duration of the project. Since development activities for the various software subsystems and successive builds of these subsystems will occur at different times, reviews will be scheduled so as to support development schedules. These reviews shall include Software Requirements Reviews (SRRs), Preliminary Design Reviews (PDRs), Critical Design Reviews (CDRs) and code walkthroughs. Affected organizations will be encouraged to send representatives to these reviews to ensure that the components are being developed as expected by members of the software community represented by the SOWG.

Software issues surfaced at all reviews will be worked and tracked by the SOWG until they are resolved. Reports of the status of these issues and actions will be maintained and disseminated at regular intervals.

4.3.4 Resource and Schedule Management

Primary responsibility for resource and schedule management lies with the providers' management personnel. Any indications, resulting from progress assessment activities or reviews, that schedules will not be met or that costs will be exceeded, will be reviewed by the Software Manager and discussed with the provider's software management representative. The Software Manager will assess the impacts of possible deviations and present these findings to the appropriate member of the Project management staff. The Software Manager will then present any significant issues to the SOWG for discussion so that other providers can offer suggestions and solutions and make any necessary adjustments.

4.4 Risk Management

The Project is conducting a risk assessment and evaluation process. The SOWG will conduct a similar process specifically oriented to risk elements related to the software development efforts. A Risk Management Plan will be produced to define the risk management terminology and procedures. The Risk Management Plan will be reviewed with the SOWG to ensure that all software providers have an opportunity voice their preferences. Risk management plans and processes may be required from Software Providers in accordance with their respective contracts. This process will depend on inputs to be generated by software providers and will consist of the following elements:

- Identification of risks
- Risk Analysis
- Risk Mitigation
- Risk Monitoring

The process will address the following classes of risk:

- Technical Risks
- Safety Risks
- Security Risks
- Resource Risks
- Schedule Risks
- Cost Risks

4.5 Configuration Management

The Project will define an approach to configuration management involving centralized, automated, on-line processes. It is desirable to have a single software CM system, however, providers may utilize proprietary systems if that is shown to be most cost-effective. In any case, all CM databases shall be available, at least for read access, to the Project, to Systems Engineering teams, and to Software Development and Integration and Test Teams either government or contractor.

The Software Manger, assisted as necessary by the SOWG, will provide support to the Project in the following areas with regard to software development:

- Develop the Project's Software Configuration Management Plan.
- Establish the Project's Software Configuration Management (CM) system.
- Serve as a member of the Project level CCB.
- Establish and maintain the Project's Software Change Request (CR) tracking data base.
- Establish and maintain the Project's Software Problem Reporting and Resolution System.
- Review CRs for software classification changes.
- Manage the SCM library and thereby control the use and revision of official copies of baseline components.
- Produce and distribute periodic Software CR data base and individual product CR status reports.
- Support Project functional and physical configuration audits (FCA & PCA) of providers.
- Review providers' Software Configuration Management Plans.

The SOWG and the software providers will work together to structure a configuration management process for the items listed below, and the providers shall also address these in their Software Management Plans or in separate Configuration Management Plans.

- Configuration Identification
- Configuration Change Control
- Configuration Status Accounting
- Configuration Authentication

4.6 Documentation Requirements

For each software segment and configuration item, the provider will identify, in the corresponding Software Management or Product Plan, the appropriate documentation to be prepared. These will include:

- Requirements Specifications
- Interface Requirement Documents
- Interface Control Documents
- Design Documents
- Integration and Test Plans and Reports
- Build and Release Plans, Test Plans and Reports
- Verification and Validation Plans

- Product Assurance Plans
- Delivery and Transition Plans
- Sustaining Engineering and Operations Activity Plans
- Users Guides
- Operations and Maintenance Guides

4.7 Deviation Procedures

Deviations can be proposed during major reviews or requested between reviews. Generally, deviations will be approved if circumstances indicate that it is advantageous to the project and any additional risk incurred from doing so is minimal and justified by the advantage gained. Deviations may not be employed to avoid proper treatment of critical software or to circumvent product assurance measures. Typical deviations might include such things as use of a non-standard higher-order language or use of a non-traditional development or testing approach.

Providers, when preparing their SMPs, shall describe any major or encompassing deviations they anticipate so that these may be reviewed early on.

5 TECHNICAL APPROACH

The NGST software engineering process will employ systematic technical approaches with appropriate adherence to accepted guidelines and standards for both development and sustaining engineering phases of the mission. Providers are required to present and distribute data products and specifications in a manner consistent with the project information infrastructure. Providers will also be required to collect data on technical performance that supports measurement and improvement of the effectiveness of technical processes.

5.1 Software Engineering Process

The NGST Software Engineering Process will be governed by a life-cycle model intended to provide a framework that:

- ensures that a thorough and systematic process is employed
- ensures that adequate opportunities for interaction are provided for all stakeholders who can beneficially contribute
- supports the generation of products useful to the development and maintenance processes

Providers are required to document in their SMPs the processes, methods, development environments and tools, standards and guidelines that they will employ at every stage of the life cycle.

5.1.1 Life Cycle Model

NGST Software Development will generally follow the flow of a traditional life cycle with the following principal phases and activities:

- Formulation Phase
  - Operations Concept Definition
  - Requirements Definition
  - Requirements Analysis
  - Architecture Design
- Implementation Phase
  - Software Preliminary Design
  - Software Detailed Design
  - Software Code and Unit Test
  - Software Integration and Test
- Operations and Maintenance Phase
  - Deployment
  - Acceptance Testing
  - Transition
  - Operations
  - Sustaining Engineering

The intention is to apply this life cycle flexibly so that emphasis is on performing useful work that contributes useful products. For cases where a particular activity would not add value, it should be modified or eliminated. Some of these activities will overlap and, in some cases, run

currently. Also, different components may be in different phases and activities at a given time as specified in Build Release Plans.

5.1.2 Formulation Phase

The Formulation Phase involves defining the system or component to be built in terms of a description of its purpose, how it will operate in the context within which it will be used, what functions it will perform, what requirements and constraints it must satisfy, and how it will be organized at the highest level. It is expected that there will be a lot of interaction between the various activities that contribute to the formulation process.

Other related activities that will be taking place during the formulation phase include planning the development and integration effort and developing initial estimates of cost and schedule.

5.1.2.1 Operations Concept Definition

The operations concept is a description of the purpose of the system to be built and descriptions of how it will operate in terms that users of the system will understand and relate to. In the case of systems that are used by other systems, the operations concept can be useful to developers of the user systems.

The purpose of the operations concept is to ensure that the right system is being built and that users will find the completed system useful. The operations concept is the foundation for validation activities.

A science mission operations concept is being developed by the Science Institute. From this top-level operations concept, the operational characteristics of segments and components can be defined. Operations concept information should encompass all modes and functions including contingency cases. Techniques for presenting operations concept information include scenarios, operations timelines, use cases, and user interface prototypes.

5.1.2.2 Requirements Definition

Requirements are clear, unambiguous, testable, quantitative, well organized, hierarchically structured statements about what the system will do including the functions it will perform, how it interacts with other entities, and how well (fast, reliably, etc.) the system will perform them. Detailed requirements shall be identified as functional, performance, and interface requirements. Functional and performance requirements are based on and derived from operations concept information. Interface requirements may depend on information from the software architecture design process (Section 5.1.2.5) to define the entities between which interfaces must be specified. Requirements for interface between segments or major systems shall be expressed in Interface Requirements Documents (IRDs).

The hierarchical structure of the requirements manifests as a set of mission requirements (see Reference 3), traceable to the Science Goals, and sets of more detailed or lower-level requirements that can be traced to the mission requirements. There may be as many as five or six levels of requirements culminating in requirements for software objects at the component level. Traceability shall be maintained between higher- and lower-level requirements. Typical designations for the levels of requirements are as follows.

Level 0 Science Goals

Level 1	Mission Requirements
Level 2	System Requirements
Level 3	Segment Requirements
Level 4	Element Requirements
Level 5	Subsystem Requirements
Level 6	Component or Unit Requirements

The highest level requirements that are purely software requirements will probably appear at level 3 or 4. Requirements should be maintained in one or more data bases viewable by all members of the project to facilitate the construction of verification matrices for use in tracing requirements to design elements and test processes. Requirements must be reviewed, discussed and approved in requirements review meetings led by the SOWG.

5.1.2.3 Requirements Analysis

Requirements analysis comprises any activities intended to ferret out the implications of requirements to provide a strong foundation for design. This may take the form of logical analysis of information requirements, event analysis, data flow analysis, or state transition analysis. This type of analysis may result in lower-level requirements, definition of algorithms, or other information specifying the nature of the processing to be done.

Requirements analysis is also used to develop hardware resource requirements for support of development and processing operations. Hardware resource requirements include such things as processor and storage capacities, and network and device throughput requirements.

Requirements analysis is the process for ensuring that the requirements are properly understood so that design may proceed. The need for requirements analysis depends on the complexity of the requirements and the detail of the operations concept information available. Software providers will indicate in their SMPs areas where requirements analysis will likely be required. The SOWG may designate areas requiring further analysis, for example, during reviews of operations concept information and requirements.

The Project will review the software requirements at a formal System Requirements Review (SRR). A Requirements baseline will be established after the completion of the SRR.

5.1.2.4 Architecture Design

Software architecture design involves identification of the principal or top-level Computer Software Configuration Items (CSCI) of a system and the allocation of all software requirements to these configuration items. Software providers will group software requirements into logical sets such that each set maps to a CSCI. As a general rule, a CSCI is established for a separable piece of the software system that can be designed, implemented, and operated independently. Other criteria that may affect the decision to designate a software entity as a CSCI are:

- critical to overall performance
- highly complex, incorporates new technologies, involves high risk, or has stringent performance or safety requirements
- higher than usual expected modification rates

- encompasses all of a specific domain of functionality
- will be installed on a separate computer platform distinct from other parts of the system
- encapsulates interfaces with other software items that currently exist or are provided by other organizations
- some part of the software is planned to be reused

Software architecture design may also involve preliminary identification of off-the-shelf components, preliminary estimates of computational resource requirements, and the allocation of software to hardware platforms.

The Project will review the software architectural design at a formal system Preliminary Design Review (PDR). A Software Allocated Baseline, will be established after the completion of the PDR. The Allocated Baseline will contain the architecture design of the system and documents showing how the requirements are allocated to the design. It shall also contain all the updated documents from the Requirements baseline, along with the architectural design specification materials.

5.1.3 Implementation Phase

The Implementation Phase includes preliminary design, detailed design, coding and unit testing, integration of all components, and testing up to the system and acceptance levels. This Software Management Plan assumes that object-oriented methods and programming languages will be used since this generally represents the state-of-the-practice at this time.

Providers are strongly encouraged to use automated tools to facilitate the development process and to follow accepted standards for presentation of design information and formatting of implementation products.

Providers are encouraged to utilize “off-the-shelf” products to the greatest extent practical as a means for reducing development costs.

5.1.3.1 Software ***Preliminary Design***

Software Preliminary Design refines the software architecture design to the point where all software components and interactions between components are identified down to the unit level. Also, principal data structures and external files are identified. Typical design and presentation approaches include object diagrams, class diagrams, entity relationship diagrams, and data base schemata. It is highly desirable that design products be viewable or downloadable from the intranet.

Final decisions are made regarding which components will be purchased “off-the-shelf” and which components will be developed, and what programming languages and development environments will be used. Opportunities for reuse of common software elements are identified.

The Software Preliminary Design is reviewed, at a minimum, in a software-only, on-project review open to members of the SOWG and a product assurance representative. Reviews will be scheduled sufficiently in advance so that SOWG members and product assurance representatives can plan to attend. Products of the Software Preliminary Design activity shall be maintained in a Software Development Folder (see Section 5.1.5.1).

5.1.3.2 Software Detailed Design

Software Detailed Design specifies the details of the computer methods and programs, data structures, and unit test approaches. Software Detailed Design products are reviewed in a peer walkthrough scheduled sufficiently in advance so that a product assurance representative and, possibly, SOWG members can plan to attend. At these walkthroughs, in depth discussion of the coding and testing techniques and approaches may be required so they must be attended by the personnel who will write and test the code, typically the same personnel who developed the detailed design. Products of the Software Detailed Design activity shall be maintained in a Software Development Folder (see Section 5.1.5.1).

The Project will review the software detailed design at a formal Critical Design Review (CDR). A Software Detailed Design Baseline will be established after the completion of the CDR. The Software Detailed Design Baseline will contain the computer methods and programs, data structures, and unit test approaches. It shall also contain all the updated documents from the Requirements baseline and Software Allocated baseline, along with the detailed design materials.

5.1.3.3 Software Code and Unit Test

Coding and unit testing are performed in accordance with the Detailed Design products. Code walkthroughs are conducted to verify that code conforms to the coding standard, that the logic and approaches are consistent with the detailed design, and that implementation details have been constructed in a reasonable and favorable manner. Unit tests are performed to verify the logic and proper execution of the code. Coded and tested units are transferred to a configuration managed software repository in preparation for Software Integration and Test.

5.1.3.4 Software Integration and Test

Planning for Integration and Test begins during the Formulation Phase with the definition of the levels of integration and the sequence of builds and releases. The system may be delivered in several builds or blocks, each of which may have several different releases with increasing levels of capability.

Test planning begins after requirements are allocated to architectural components. A general method for verifying each requirement is identified for inclusion in the test plan. Groups of requirements are assembled based on similarity of function and commonality of test approach. A test procedure is identified to verify requirements in each group.

Each provider shall prepare an Integration and Test Plan that describes the sequence and levels of integration from the component level up to the level of the delivered system to be provided by that provider. The I&T Plan shall describe the facilities and approaches to be employed in this process including test tools, simulators, actual flight hardware, engineering test units, and components of interfacing systems. Automated test methods shall be used wherever practicable to facilitate regression testing and re-testing.

Subsequent, higher levels of integration and testing, including end-to-end system testing, verification and validation, and certification are discussed under Product Assurance in Section 6 of this document.

5.1.4 Operations and Maintenance Phase

The operations and maintenance phase encompasses activities involving the deployment of completed systems, the acceptance of the systems by user organizations, and the transition of those systems to supporting the activities of users and operators who are preparing for or conducting NGST Observatory operations including software system maintenance. This portion of the SMP will be revised as the NGST program develops. There may be differences among the various segments and components

5.1.4.1 Deployment

Deployment involves the distribution of copies of the software to sites where it will be operated and installation of the software on the designated computer equipment including any initial configuration needed to bring the newly installed software into fully operating status.

5.1.4.2 Acceptance Testing

Acceptance testing is the final testing activity whereby the entity receiving the products participates in a formal test of the system using an agreed upon set of test procedures that demonstrate the proper functioning of the system, at the level of user interaction. The Acceptance Test Procedures shall be designed to demonstrate the operational readiness of all functional and performance capabilities of the system as called for in the requirements. Acceptance testing may be conducted as part of the Verification and Validation activity (see Section 6.3).

5.1.4.3 Transition

Transition involves the training of personnel and development of personnel procedures for operating the system to fulfill its intended purpose.

Planning for Deployment and Transition typically begins at a very high level around PDR and becomes successively more refined throughout the Implementation Phase. Software personnel may be required to support activities related to facility preparation, and hardware installation and checkout prior to software deployment.

5.1.4.4 Operations

The operations phase for NGST is nominally planned to last for 10 years. Simulated operations, a logical follow-on from the validation process, will begin sufficiently before launch so that adequate training can be conducted for support of both the deployment phase and normal operations.

Operations procedures will be developed by personnel responsible for conduct of science and spacecraft operations. These procedures are likely to be based on procedures developed by Spacecraft and Science Instrument developers who will most likely remain involved, at least during some initial or transition period, until such time as operations are running smoothly.

Software providers will be responsible for development of User Guide or Operations Manual type information, probably housed in online repositories for electronic access from operations work stations.

5.1.4.5 Sustaining Engineering

Sustaining engineering is required for all flight and ground software, and for the software and tools related to sustaining engineering environments. The sustaining engineering environments will most likely be identical to or close variants of the development and validation environments used for software implementation and for data and procedure development.

Sustaining engineering consumes a significant portion of the project life-cycle cost. Consequently, considerations for this should begin as early as the architectural design phase. Particular regard should be given to required facilities and personnel, and to the impact of architectural decisions that enhance the use of common elements thereby reducing maintenance complexity.

5.1.5 Other Software Engineering Considerations

This section discusses software engineering topics that do not fit conveniently into the discussions above related to life cycle phases.

5.1.5.1 Software Categorization and Classification Policy

Each NGST software subsystem or component shall be classified into one of three categories depending on how critical that subsystem or component is to the safety and operation of the mission. The three categories are defined in Table 5-1. Once classified, a Software Change Request is required to change the classification. Requests to change classification will require review by the software manager. Providers shall describe in their SMPs how their software development practices will differ among the three categories.

Table 5-1. NGST Software Classification

CATEGORY	NAME	DESCRIPTION
1	Mission Critical	Software that directly impacts the safety of the spacecraft (such as safing system software); requires highly stringent development, testing and verification methods.
2	Operations Essential	Software that needs to operate properly to support operations or sustaining engineering; requires “industry best practices” for software development, testing and verification.
3	Temporary	Software that does not need to be maintained because it is used only once or over a short interval of time and will not be needed subsequently. Any products used in operations, produced by temporary software, must be verified in accordance with Category 2 practices.

5.1.5.2 Software Development Folders

Software Development Folders (SDFs) are a means for tracking and documenting the development of software components. SDFs contribute to a systematic process for development of software units, support information gathering and process improvement, and protect against

losses due to unanticipated absences of development personnel. Information is placed in SDFs during Software Preliminary Design, Software Detailed Design, Software Code and Unit Test, and possibly during Integration and Test.

Each provider shall establish and document procedures for creating and maintaining SDFs in their SMP. SDFs shall meet the following requirements:

- The provider shall document the development of each computer software unit (CSU), computer software component (CSC), and CSCI using software development folders (SDFs). The provider shall establish a separate SDF for each such software item or logically related group of items.
- The provider shall establish the folders within one month after the completion of the preliminary design review and shall maintain the SDFs until the delivery of the final product and completion of the contract.
- The SDFs shall be made available for Project review upon request. SDFs may be generated, maintained, and controlled by automated means. To reduce duplication, SDFs should not contain information provided in other documents or SDFs.
- The SDFs shall include (directly or by reference) the following information:
  - Design requirements
  - Design considerations and constraints.
  - Design documentation and data
  - Schedule and status information
  - Source code.
  - Test requirements and responsibilities.
  - Test cases, procedures, and results.
  - Configuration control activities and change reports to include traceability of the requirement for change, the authorizing authority, and the changes made to software/documentation.
  - Results of walkthroughs, reviews, and inspections, with findings and recommendations and actions taken.

5.1.5.3 Data Generation and Management

In addition to software components involving computer code, NGST will require significant data components that will play a variety of roles in ground and flight systems. Data sets will be classified by how they are used operationally. This includes how the data are created, how the data are stored and accessed, who provides the data, who uses the data, how long the data are retained, how often and under what circumstances the data are modified, relationships to other data, and how the data are validated and certified.

For example, data sets may be system related in which case they might be treated much the same as software components; they may be spacecraft related requiring occasional update by spacecraft system engineers; they may be used for test purposes requiring early generation and subsequent update as system requirements evolve; or, they may be routine operations oriented constituting a regular flow of information through the system.

Software providers shall develop basic information for all data sets identified during preliminary design so that refinements to operations concept information can be made and operations planning can proceed, including the specification of the necessary data management systems.

This information will be updated at PDR and refined at CDR so that changes can be reflected in operations planning and procedures documentation.

The required information for each type of data shall include:

Name or type of data
Description of the data
How the data are created and by whom
How the data are stored
How the data are accessed and by whom
Volume of the data
Data retention and archive requirements
How often and under what circumstances the data are modified
Relationships to other data
Validation and certification requirements

5.1.5.4 Problem Reporting

Each provider shall operate an automated problem reporting system that can accept problem reports from developers, testers, and users of the systems being developed. The problem reporting system shall be able to track and report the status of all problems that have been recorded and selectively report categories of reports based on the recorded fields. It is recommended that one large encompassing problem reporting system be constructed to serve the entire project. This problem reporting system could be combined, as an additional capability, with the change control and reporting system referred to in Section 4.5 that tracks the progress and status of change requests.

5.2 Data Product and Specification Structure

The data products and specifications to be prepared in the course of development activities are tabulated below with explanatory comments.

Table 5-2. NGST Software Specifications and Data Products

DATA PRODUCT	COMMENTS
Software Management or Product Plan (includes or rollout documents for) Implementation Plan CM Plan Risk Management Plan Product Assurance Plan	Initial draft prepared during Formulation Phase, revised for PDR and CDR.
Interface Requirements Document	Preliminary IRDs between major segments are being developed by Phase 1 prime contractors with SOWG support. They will contain sections to address the software aspects of the interfaces. These include: · Ground System to Observatory IRD · SSM to ISIM IRD The ISIM Project will prepare the ISIM to Science Instrument IRD. Other IRDs may be defined as appropriate between lower-level software components. Final IRDs are generally required by PDR for the components involved.
Interface Control Document	Preliminary ICDs are prepared at the start of detailed design. Final ICDs are generally required by CDR prior to commencement of fabrication.
System Requirements Specification	Preliminary SRS is required by software System Requirements Review. Final SRS is due at software PDR
Design Document	Software design documentation is prepared during preliminary and detailed software design activities. It may be produced largely with automated tools. Design documentation is finalized after the software PDR or CDR for that component.
Build and Release Plans	Build and Release Planning begins during architectural design and continues through CDR.
Build and Release Test Plans and Reports	Preparation of Test Plans begins during definition of the entity (build or release) to be tested. Reports of the results of testing activities are prepared within 10 days of the completion of the test activities.
Integration and Test Plan and Reports	Integration and Test Planning begins during architectural design for system levels and continues through CDR for subsystem and component levels. Reports of the results of testing activities are prepared within 10 days of the completion of the test activities.
Verification and Validation Plans and Reports	Draft V&V Plans should be in place by the end of the Formulation Phase and should be finalized early in the Implementation Phase.
Delivery and Transition Plan	Delivery and Transition Planning should begin no later than CDR and be completed by Acceptance Testing.
Sustaining Engineering and Operations Activities Plan	Sustaining Engineering Planning should begin no later than CDR and be completed before any transfer of maintenance responsibilities begins.
Users Guide	User documentation should begin no later than CDR and be completed by System Acceptance Testing (see section 6.4).
Operations Manual	Operations documentation should begin no later than CDR and be completed by System Acceptance Testing (see section 6.4). Should cover software and data components.
Maintenance Manual	Maintenance documentation should begin no later than CDR and be completed by System Acceptance Testing (see section 6.4). Should cover software and data components.
Data Component	Data components will be treated in accordance with procedures for the type of data. Generally, persistent data will be configuration managed as either a software system component or an operations data component.
Software Component	Software components will be placed under configuration management, in approved repositories, upon submission for integration after completion of unit testing.

5.3 Technical Performance Measures

The Project will use metrics as management and quality indicators. To support this use, each provider shall establish and implement a software metrics program that will enhance their capabilities to manage and direct the software development process and facilitate the growth of product quality.

Software metric data shall be collected that support the quantitative evaluation and analysis of trends for the entire life cycle development process and the products that it generates. The specific metrics to be collected will be defined by PDR. Examples of metrics that may be useful include:

- Requirements established/modified/deleted
- Software change requests opened/closed/remaining open/cumulative
- Estimated source lines of code
- Design/code complexity index
- Percent memory, CPU, and I/O utilization
- Source code growth rate
- Detected code error rates
- Problem reports opened/closed/remaining open/cumulative
- Effort data (staffing profile)
- Development CPU time usage and trends
- Number of audits, inspections, reviews, walk-throughs , etc.
- Development activity status

The collection, reporting and analysis of metrics shall be automated to the fullest extent practicable and shall be performed at appropriate intervals or nominally on a monthly basis. Metrics shall be provided to the Project both as raw data and in graphical form.

6 PRODUCT ASSURANCE

This section identifies processes for ensuring that all NGST software-related products meet the requirements and standards that have been identified as essential to achieving NGST Software Development Project goals.

6.1 Quality Assurance

Quality Assurance for this project will be conducted in accordance with the GSFC Quality Management System which consists of all the policies, processes and procedures that contribute to meeting GSFC's ISO 9001 quality goals as expressed in Reference 5, The GSFC Quality Manual, GPG 8730.3C. For Flight Software, the GSFC Information Systems Center, Code 582, will direct the Quality Assurance process.

Quality Assurance involves establishing standards for the preparation of data products, monitoring the products to ensure that they conform to the standards, and recommending corrections when they do not. Standards are discussed further in Section 6.2.

Each software provider shall describe their approach to software quality assurance. This description may be either part of their Software Management Plan or in a separate Software Quality Assurance Plan.

6.2 Applicable Standards

Appropriate standards should be used as guidelines for development of software, data and documentation products. In many cases, however, standards for presentation, formatting and style are imposed by automated tools that are selected for a variety of features and benefits. Consequently, it is not prudent to rigidly specify that certain standards be followed because that could preclude adoption of tools that provide significant advantage. It is important that sound standards are identified and that the intent of the selected standards are met. Consequently, the selection of tools should consider the methodologies employed and the features of the output products that the standards are intended to engender.

The designation and utilization of standards is particularly recommended for the following items:

- Requirements
- Design
- Coding standards
  - Formatting Conventions
  - Usage Rules
  - Portability – avoid non-standard usage
  - In-code documentation
    - Prolog – Arguments, I/O, Exceptions, Change History, Version
    - Algorithm Description
    - Variable Description
    - PDL
- Unit Test
- Documentation
  - Planning documents

- User and Operator Manuals

Each software provider will identify in their Software Management Plan the standards that will be used in their software development processes. Sections 2.2 and 2.3 suggest various standards that may be employed.

6.3 Verification and Validation

Verification ensures consistency from product to product along the development path and involves constructing verification matrices showing the allocation of requirements to both software components down to the module level and to test processes to ensure that all functional and performance requirements are met. Verification also involves independent review and or testing of all development products at a system level. Validation consists of testing and utilizing all development products in a real or simulated operational environment, in the manner intended for users and operators, to ensure that the system meets the needs of the user and operator community. End-to-end system and acceptance test functions, or portions of them, may be conducted as part of the verification and validation activities.

Validation shall be performed, to the greatest extent practicable, by persons independent of the development activities.

Each provider shall describe in their Software Management Plan the specific processes and procedures for performing verification at the component and system level. Verification at the mission level and system validation will be described in an NGST Project Integration and Test Plan.

6.4 Safety Assurance

Safety Assurance requires that all systems and facilities are designed and maintained so as to cause no physical harm to workers, users, or observers. For NGST software, this will primarily involve ensuring that the physical environments where software development and testing are performed are free of hazards and conform to standard workplace safety standards and guidelines. Software commanding of spacecraft mechanisms in testing environments may also be a consideration.

6.5 Security

Security Assurance involves all necessary measures, both technical and procedural, to ensure that (1) all processing systems supporting the conduct of NGST flight operations cannot be accessed from outside the community intended for its use; and (2) data products generated by these systems, as well as the systems themselves, cannot be altered by unauthorized persons either maliciously or unintentionally. This will include measures to ensure computer security, information security and physical security.

6.6 Certification

Certification of software and data components for use in the direction or execution of spacecraft flight operations involves a methodical accounting process for ensuring that every requirement has been tested, every change has been verified, and every data item has been checked. Procedures for accomplishing this for NGST software are TBD.

7 ABBREVIATIONS AND ACRONYMS

CDR	Critical Design Review
CM	Configuration Management
CMP	Configuration Management Plans
COTS	Commercial Off-the-Shelf
CPU	Central Processing Unit
CR	Change Request
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
CSU	Computer Software Unit
ESC	Electrical Systems Center
FCA	Functional Configuration Audit
GSFC	Goddard Space Flight Center
I&T	Integration and Test
I/O	Input/Output
ICD	Interface Requirements Document
IEEE	Institute of Electrical and Electronics Engineers
IRD	Interface Requirements Document
ISC	Information Systems Center
ISIM	Integrated Science Instrument Module
NASA	National Aeronautics and Space Administration
NGST	Next Generation Space Telescope
OTA	Optical Telescope Assembly
PCA	Physical Configuration Audit
PDL	Program Design Language
PDR	Preliminary Design Review
SDF	Software Development Folders
SI	Science Instrument
SM	Software Manager
SMP	Software Management Plan
SOWG	Software Operations Working Group
SSM	Space Support Module
STScI	Space Telescope Science Institute
V&V	Verification and Validation
WBS	Work Breakdown Structure
WWW	World Wide Web